High-temperature fatigue crack growth resistance of thermomechanically and heat treated cast Ti-Si-Al-Zr composites

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An operating temperature of conventional titanium alloys is limited by 300 – 500 °C. The known Ti-based composites possess high strength under tensile and bend loading, fracture toughness under static loading in the temperature range from 20 °C up to 600 – 650 °C, but there is the need to increase the operating temperature range of their utilization up to 700 – 800 °C.

The objective of this work is to evaluate reliability of Ti-Si-Al-Zr composites using the fatigue crack growth resistance (FCGR) data (fatigue crack growth rates, da/dN, versus stress intensity factor range, ΔK, dependences) obtained in the temperature range of industrial composite parts operation.

Modifications of Ti-4Si-4Al-5Zr composite manufactured with electron-arc smelting (variants M0 and T0) and using the thermo-mechanical deformation of 40 % and 90 % (variants M4 and T1, respectively) and also heat treatment (quenching) after casting (variants M01 and M022) have been examined.

The single edge specimens were loaded under three-point bending at cyclic frequency of 10 Hz, stress ratio of 0.1. The FCGR tests were carried out in the laboratory air at the temperature of 20 ˚C and 700 ˚C. Several control tests of the composites were performed at the temperature of 800 ˚C. Optical and scanning electronic microscopy was used for analysis of microstructure and fracture micromechanism of the materials.

In general the influence of high temperature on the crack growth of tested materials depends on ΔK range. It is negligible in threshold (ΔK_{th}) and critical (ΔK_{fc}) regions of the $da/dN - \Delta K$ diagram and the maximum acceleration of the crack growth occurs in middle ΔK region. The cast modifications after quenching in the oil and in the water were the most sensitive to the negative influence of high temperature. The satisfactory fatigue crack resistance at the temperature range of 500 – 700 ^{o}C was demonstrated by cast and thermodeformed modifications.

The results obtained at 700 ^{o}C showed that the common trends of FCGR improvement by the thermo-mechanical treatment are the same as at the temperature of 20 ^{o}C. In general material does not lose FCGR taking into account the threshold ΔK_{th} and critical ΔK_{fc} meanings. Fatigue crack growth mechanism by void coalescence dominates here.

Particular investigations of composites at the temperature of 800 ^{o}C confirmed the domination of the mentioned above fracture micromechanisms. At this temperature only cast modifications without thermo-mechanical and heat treatment still have satisfactory fatigue crack growth resistance.